consumption pattern of industrial and household consumers and lower their energy consumption and enhance energy efficiency. For industrial consumers, one of the key DSM programmes is the Perform, Achieve and Trade (PAT) scheme, which has created a market for trading of energy saving certificates. These certificates are issued to industries that reduce their specific energy consumption beyond the target. Apart from this, Energy Efficiency Services Limited's (EESL) Unnat Jyoti by Affordable LEDs and Appliances for All (UJALA) scheme, the world's largest domestic lighting programme, has significantly contributed to energy efficiency improvement by promoting the use of LEDs and energy efficient fans and tubelights.

Launched in 2015, it is one of the most-effective DSM initiatives in the country for promoting energy efficiency in the lighting industry. Under the scheme, LED bulbs are distributed to households at 40% of the market price, while bearing the total upfront investment and risk coverage. The key success factor behind the scheme has been the decline in LED prices owing to demand aggregation and bulk procurement. EESL is also implementing a national scheme, PAVAN, under UJALA, for the distribution of BEE 5-star-rated energy-efficient fans.

One of the key challenges in LED adoption across the country has been pricing and availability. Cheap Chinese imports and inadequate demand have left domestic players with little incentive to manufacture LED lamps. However, due to government initiatives, the Indian LED lighting market reached a value of $3.58 billion in 2020 as per International Market Analysis Research and Consulting Group (IMARC Group). The BEE has made tremendous efforts towards energy efficiency. Till 31 March 2020, BEE had rolled out six PAT cycles with a total of 1073 designated consumers covering 13 sectors. It is projected that the total energy savings of about 26 MTOE, translating into avoiding about 70 million tonne of CO_2, will be achieved by March 2023.[4] It has also set up an online knowledge exchange platform

4 Details available at https://beeindia.gov.in/sites/default/files/press_releases/Brief%20Note%20on%20PAT%20Scheme.pdf

to facilitate peer-to-peer learning and exchange of best practices, and raise awareness about innovative approaches to energy management and new technologies (knowledgeplatform.in). A mobile application to help consumers make energy-efficient purchasing decisions (www.beestarlabel.com/Home/MobileApp), and an online platform, including an online product registry (www.beestarlabel.com), have been also developed.

Utility Initiatives

Apart from various central government schemes for promoting DSM, a number of utlity-level initiatives are under execution. In June 2019, BYPL partnered with The Energy and Resources Institute, Panasonic India, and the Council on Energy, Environment and Water for its DSM programme – a behavioural energy saving app, green division concept, and solar microgrids with battery storage. These initiatives hold the potential to save around 380 MUs of electricity.

Apart from this, BESCOM Bangalore has proposed to implement the Distribution Energy Efficiency Project (DEEP) by providing dynamic reactive compensation for a power factor improvement scheme on select 11 kV feeders on a pilot basis. TPDDL replaced 9089 non-star rated air conditioners under the AC replacement scheme. This yielded deemed load reduction of 5.94 MW and deemed savings of 7 MUs, annually.

At the utility level, one of the widely adopted DSM strategies is demand response, wherein the companies aim to reduce or shift their energy consumption from the peak hours of the day, when the demand for electricity is the greatest, to leaner demand periods. Tata Power (Mumbai) rolled out India's first demand response programme as part of its DSM initiative in 2014. Under this scheme, the cumulative demand response curtailment of about 14.45 MW was achieved. Another demand response pilot was implemented by BSES Delhi, wherein the 500 largest consumers of BYPL with a load of over 500 kW each were enrolled. They were requested to voluntarily reduce their electricity load as and when required, especially during peak hours, in return for Re 1 per unit. Another demand response programme by Jaipur Vidyut Vitran Nigam Limited in 2013–14 helped achieve power savings of over 21 MW.

The Road Ahead

The market potential for energy efficiency services in India is estimated to be between $10 billion and $35 billion per year. However, opportunities remain largely untapped. As per Alliance for an Energy Efficient Economy (AEEE), the current combined revenues of energy service companies are only $150 million (excluding EESL's revenues). Meanwhile, the same market has exceeded $16 billion in China and $7.6 billion in the US. As regards to the focus, almost all the projects are in the industrial sector, with the public sector energy efficiency projects accounting for only 1%.

On the basis of global experience it is evident that governments play a crucial role in establishing conducive framework conditions for energy efficiency by coordinating policies across all the sectors to address issues such as data collection, pricing, and market barriers. Further efforts should be made to integrate and prioritize energy efficiency in energy system/urban planning, as well as in government missions and initiatives such as Make in India, Smart Cities Mission, Atal Innovation Mission, and Atal Mission for Rejuvenation and Urban Transformation.

Reliable and timely data on energy end-uses, markets, technologies, and efficiency opportunities in all the sectors help in the development of effective energy efficiency strategies and policies. However, data gaps still remain in India, notably from the industrial sector (where more than 40% of energy use and more than 50% of electricity use are not specified). Further efforts to

improve the investment climate for energy efficiency projects are warranted. Access to finance is facilitated through a partial risk guarantee and a venture capital fund for energy efficiency. In micro, small, and medium enterprises (MSMEs), financial assistance and low-interest loans are available for energy efficiency measures. Designing national programmes that effectively reduce MSME energy demand is a challenge, especially as there are more than 63.4 million MSMEs in India. To overcome these challenges, the central and state governments could include facilitating access to equity and venture capital, risk mitigation through, for example, guarantee schemes, and by providing incentives both for energy service companies and for customers.

International experience shows that energy management systems such as ISO 50001 can reduce company-level demand by 10–30% within the first year of adoption. But by end of 2017, only 1613 sites in India had ISO 50001 certification compared to more than 30,000 in Germany alone, where uptake has been promoted through tax incentives. The government could also consider incentivizing the use of energy management information systems that enable real-time monitoring and management of energy use. Implementation of such systems in industry shows an average of 10–20% reductions in energy use.

Also required is expanded coverage of India's mandatory minimum energy performance standards and labels to industrial equipment such as compressors, pumps, fans, and boilers.

Furthermore, there is a need to mainstream the role of DSM in the ongoing electricity and climate change reforms. For example, clear DSM performance milestones should be set under the Ujwal DISCOM Assurance Yojana (UDAY) programme, in the form of quantum of energy savings and/or peak demand reduction, with a monitoring and verification mechanism. Additionally, there is a need to review the incentive mechanism proposed under UDAY to adequately compensate the DISCOMs for scaling up DSM activities. Despite the existence of DSM regulations in about 17 states and 7 Union Territories, enforcement of those regulations continues to be limited. There are several challenges in their implementation such as lack of commitment by the state DISCOMs and governments, weak financial position of DISCOMs, and uncertainty regarding the large-scale impact of DSM pilot projects. Moreover, integrated DSM solutions have to be scaled up by considering both water and energy-side interventions with appropriate delivery models, especially to maximize resource savings in the agriculture-intensive states. On the delivery front, DSM delivery models such as demand aggregation, bulk procurement, on-bill financing, standard offer, and standard rebate have gained tremendous stakeholder confidence in the wake of EESL's UJALA success.

India's Power Minister recently stated that 'one unit of energy saved is 1.3 units of energy generated'. This must be considered in principle and reflected accordingly in the electricity governance and policy framework.

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ELECTRIC VEHICLES-DREAM OR REALITY

With the hype generated around nuclear power busted in less than two decades, one of the most sought after questions is 'Will electric vehicles meet the same fate?'. How viable are electric vehicles (EVs)? Is this option a hype or reality? In this article, **Dr Neeraj Kumar** analyses why we should be careful regarding the euphoria surrounding electric vehicle success.

Viability of Electric Vehicles

The birth of nuclear power for the so-called peaceful purpose started long back in the 1950s, and the official announcement was made by President Dwight D. Eisenhower in his 'Atoms for Peace' speech in 1953, while addressing the United Nations. The speech revolved around international collaboration for the development of nuclear power for peace. At that time, nuclear power was meant for destruction only. In 1954, the Soviet Union installed a channel-type reactor, moderated with graphite and cooled by water. A similar reactor later exploded at Chernobyl in 1986. Other countries followed the trends and there was huge growth and investment in nuclear sector during the 1970s. However, after a rosy forecast, the hype generated around nuclear power busted in less than two decades. 'Will electric vehicles meet the same fate?', this is one of the most sought after question. How viable are electric vehicles? Is this option a hype or reality? After a careful examination of the past and projection of the future, one may expect to find suitable answers.

The Indian automobile industry has successfully negated the roller coaster ride of the demand of domestic market for passenger vehicle and two wheelers over the past decade. Since its inception, the Indian automobile industry has witnessed and overcome different challenges including low or no growth. This industry, riding on various obstacles, has become the fifth biggest market for passenger vehicles and expected to achieve third position in the world in terms of volume by 2026. In addition, India is the biggest market for two wheelers.

The auto-market has evolved during the past decade. The priority of buyers has changed from entry level car to much higher level. There is a marked shift in the preference of buyer, and the inclination is more towards sports utility vehicles. It is worth mentioning that commercial vehicles, unlike their older versions, have become modern, fuel efficient, and comfortable. The admiration of leisure riding has opened the door for expansion of powerful motorcycles market. Further, the auto-sector has experienced a rapid dieselization, especially during generous subsidies period, which led to a sharp decline in the sales of petrol-fueled cars. The cost of diesel was around only a third of petrol, which was enough to tilt the market in favour of diesel-driven vehicle. However, from the last few years, central government of India, riding on prevailing lower crude price compared to the dizzy highs of 2008, started deregulating prices of petrol and diesel. This resulted in narrowing the price difference between petrol and diesel and which led to change in the customer behavioural patterns. The demand of diesel car surged and its share reduced to 25% from around 50% a few years ago.

Dependence on Crude Oil and its Effects

Vehicular density has increased to such an extent that the emissions from vehicles has become an area of concern for not only the government but also the common citizen. The world surface transport is primarily propelled by petroleum-derived fuels. This pompous dependence on crude products and associated economic and environmental issues have simulated the ministries to take steps to find immediate solution. Major emissions from internal combustion engine includes carbon dioxide (CO_2), carbon monoxide (CO), unburned hydrocarbons (HC), sulphur

dioxide (SO_2), aldehydes (H—C—O compounds), lead, particulates, and nitrogen oxides (NO_x). The last two are more prominent in diesel engine. The average composition of exhaust emission for a medium-size vehicle is shown in Figure 1. These emissions are considered as hazardous to human and precursor for many secondary reactions, which basically degrade the environment.

Initial efforts were limited to oxygenated fuels such as compressed natural gas (CNG) and liquified petroleum gas (LPG). In addition, some renewable fuels, including biodiesel and ethanol, were also introduced. However, the factual transference in mobility architecture of India was started in 2017. Some mega projects announced were high-speed rail project and Hyperloop, which reflected the Indian government's seriousness in providing sustainable transportation solutions. However, the government's biggest ambitious plan is to transform the transport sector through mass-scale shift to electric vehicles by 2030 from the present petroleum propelled vehicles. This metamorphosis includes all vehicles including personal and commercial. The concept of 20 moving parts in electric vehicles against 2000 in petroleum-fuelled vehicles has also

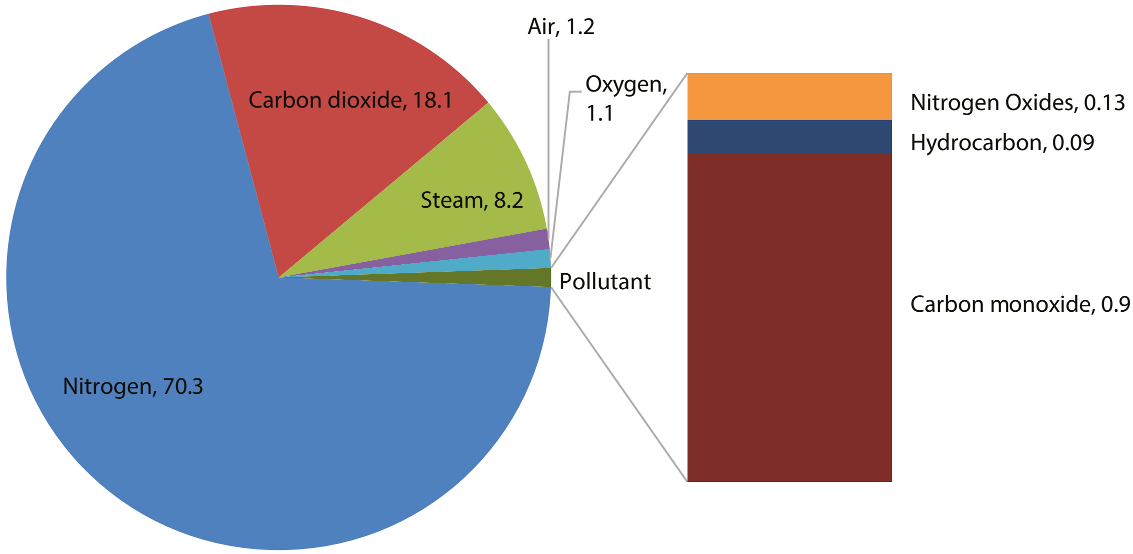

Figure 1: Average composition of exhaust emission for a medium-size vehicle

motivated the government to put their weight behind electric vehicles, beside its environmental benefits. In addition, electric vehicles have the potential to reduce the requirements of liquid fuels as well as dependency on certain countries, which is vital in the case of political turmoil. The government is also pursuing the automaker to shift to electric by announcing subsidy to the customer. India has also taken firm step to move towards electric vehicles by announcing 16% lower GST (goods and services tax) for electric vehicles in comparison to those of vehicles propelled by internal combustion engine. Tata Motors Ltd and Mahindra & Mahindra Ltd have introduced full electric vehicles in India, while Maruti Suzuki India Ltd and Toyota Motor Corp. are selling hybrid versions. While this transformation has elements of joy and celebration, this heuristic approach can create some debate as it presents steep challenges to be dealt with before its actual implementation. The advent of electric vehicles has stimulated policymakers and industry to go green; however, speed humps in policy and implementation, raw materials, and emission are some hurdles that have to be crossed for successful execution of electric vehicles.

Key Issues Related to Electric Vehicles

The success of electric vehicles lies predominately on the prospects of battery. The major issues revolve around physical availability of raw material, disposal, charging, and battery thermal management system. Some of the major issues are described in detail here.

Availability of Raw Materials

One of the factors that goes in favour of electric vehicles is its ability to wean the automobile manufacturers and customer from its dependence on limited and fast-depleting fossil fuel resources. In addition, it can facilitate freedom from dependency on import of crude oil to cater to the energy needs. The potential of Lithium-ion batteries was well recognized and commercialized in consumer electronics in the starting of the 1990s. The application of Lithiumion batteries is further extended to electric vehicle propulsion system. The driving factors are high energy and power density and long cycle life of Lithiumion batteries. Lithium, cobalt, manganese, and graphite used extensively in Lithiumion batteries are not copiously available. In fact, these are considered as critical minerals for national security and the economy in the US. These materials are largely consumed in consumer electronics and other areas including electric vehicles and stationary power storage. The demand for alkali metal lithium is rising rapidly, mainly due to sharp increase in global demand of electric vehicles and electronic goods such as laptops and cell phones. Besides this, lithium also finds its application in glass and ceramics industries. The application areas of lithium are shown in Figure 2. Riding on the intense demand, the annual production of lithium rose from 25,400 to 85,000 tonne during a period of 10 years, between 2008 and 2018. The reserve of lithium and cobalt,

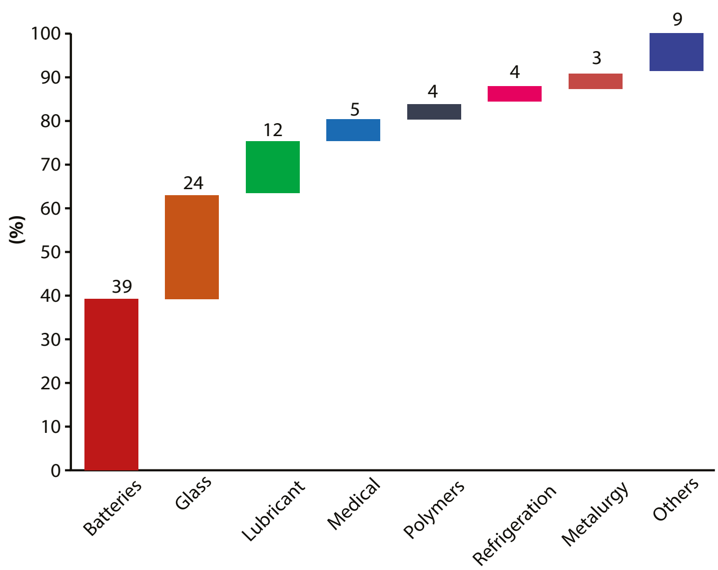

Figure 2: Lithium application in different sectors

rare metal critical for building batteries, are confined in a few topographies making accessibility to these resources a tricky situation. The major contribution to lithium reserves comes from Chile (8 million tonne), Australia (2.7 million tonne), Argentina (2 million tonne), and China (1 million tonne). Recently, Atomic Minerals Directorate has discovered lithium reserves in Southern Karnataka district, India, which is estimated to be of 14,100 tonne. However, lack of naturally occurring cobalt presents a bigger problem. The second, probably even bigger, issue is that most of the reserves of cobalt are predominantly located in the Democratic Republic of Congo. However, the lack of economic and political stability in Democratic Republic of Congo makes it one of the worst places for doing business. These circumstances could lead to a situation which is quite similar to that of importing oil and buying gas fields overseas at the expense of foreign exchange. In addition, with the increase in useability, the cost of lithium and cobalt is also of concern as their costs are dramatically increasing.

China's Dominance Over Lithium Reserve

Even though solar cell was invented in America, China is the world leader in the manufacture of solar panel and dominates the global market. In the pursuit to control global production and distribution, China seems to follow the same strategy for lithium ion battery too. It has already surpassed the US and become the largest producer of electric car and that makes the situation more alarming. It is reported that growth in electric, plug-in hybrid and hydrogen-powered vehicles are expected to grow by 20% by 2025 owing to advancement in technology and competitiveness. As a result of rapid surge in demand, China has become the largest consumer of lithium globally.

It is expected that requirements of cobalt will grow by 11% while the demand for lithium will increase by 3% by 2025 compared to those in 2015, due to rise in demand of lithium ion battery. As already mentioned, the major chunk of reserve is concentrated in a few countries which has initiated a race among powerful countries to control the reserve of lithium and cobalt. In order to establish monopoly over lithium reserve, Chinese firms have started acquiring assets in countries that have substantial reserves. As per Reuter reports, China has direct or indirect control of around 50% of the lithium extraction and is expected to grow further due to aggressive policy of Chinese entities. China has sped up its investment to secure a firm grip on the emerging lithium industry and mining operations in South America, including Chile, and Australia, and it is reported to have invested $4.2 billion in lithium deals in the last two years in South America alone. It is also increasing its stakes in mining and supply of cobalt, an another important ingredient of lithium ion. In addition, China also has additional lithium reserves in its own country and much greater lithium production. Chinese lithium firm Youngy Co. is building a lithium ore processing plant in Sichuan province to process at least 1.05 million tonne of spodumene each year. As per the prediction of Goldman Sachs, the contribution of China in supply of electric vehicles may increase to 60% of global demand.

Although India, Germany, South Korea, and Japan are trying to counter the Chinese monopoly, however, China is far ahead. In a recent reversal of fortunes, North America and Europe have discovered lithium, which may affect the Chinese dominance in future. However, the Chinese dominance will remain an unavoidable geopolitical complexity that will continue to haunt

the future supply of lithium and cobalt. In many years to come, China will dominate and play a crucial role in manufacturing and supply of electric vehicles through its firm control of lithium ore and strong supply chains. In addition, this will also dictate the country's energy security priorities that revolve around lithium, cobalt, and other key raw materials for manufacturing electric vehicle batteries. It will be a crucial factor for the energy security in the perspective of current India and China relation.

Emissions

The hype created around electric vehicles and projection of internal combustion engine propelled car as significant contributor of environment pollution have a long-lasting impact on the human mind. The hype has

intensified the popularity of electric vehicles to such an extent that these cars will become ubiquitous resource for transportation. Although electric vehicles are promoted as green vehicles with zero pollution, they also emit emissions if examined carefully. Electric vehicles are propelled with the help of batteries and these batteries, to perform their stated function, need to be charged frequently and, in this way, create huge demand of electricity. The electricity must be generated by the power plant and transmitted to the area of demand. However, internal combustion engines supply the electricity in the case of hybrid vehicles. Majority of the electricity is generated from conventional energy resources, with coal fire plant having the major share. The conversion of electricity accounts large losses in the tune of 40–50%. This may increase further with the ageing of the plants. Additional, 5%–20% losses occurred due to combination of different losses such as losses occurred during transportation of electricity from source of generation to the end users, losses due to charging and discharging of batteries, and losses due to operation of batteries in higher temperature range. If all the losses are accounted, it will be probably be in the range of those of internal combustion engine. It is also worth mentioning that the emission generated and global carbon footprint created during the production and transportation of electricity is of great concern. The only potential difference in emission generated in both the cases is area of where the emissions are released. With increasing demands, the production of electricity is bound to increase, and, hence, the emissions. Though the emissions are released to open or less populated areas, they still increase the global carbon footprint and the effects of these will be more pronounced in the near future.

The holistic approach to life cycle analysis of battery electric vehicle including energy consumed during generation of electricity and production of battery clearly indicate that GHG (greenhouse gas) impact is not as substantial as advertised. The true benefits of electric vehicles can be estimated by considering three factors: first, the release of CO_2 during fuel extraction, refining and transportation along with during production and distribution of electricity. The second factor is release of CO_2 during the production of energy, which is required for extraction of cobalt, lithium, rare earths, etc. which are considered as critical raw materials for manufacturing of batteries and electric motors. In addition, huge amount of water is required for such processes. The last factor to be considered is the toxicity involved during disposal or recycling of spent batteries. Moreover, the construction of a new electricity infrastructure, capable of recharging millions of BEVs (battery electric vehicles), will require further raw materials and energy consumption (with consequent CO_2 emission), and may be limited by the availability of critical materials.

Another emission concern is disposal of used batteries. With unrestrained expansion in electric vehicles sales in the near future, the pile of spent lithium-ion batteries is bound to grow, which will lead to a serious environmental issue. Currently, only 5% of the batteries are being recycled and only around 50% of the materials are recovered. Around 2 million metrictonne per year of used Lithiumion batteries are expected to be dumped in landfills by the end of 2030 due to absence of established recycling technology and clear-cut policy. Metal oxides or phosphates, aluminium, copper, graphite, organic electrolytes with harmful lithium salts, polymer separators, and plastic or metallic cases are the basic components of Lithiumion batteries. This means disposal of Lithiumion batteries will eventually lead to substantial increase in toxic waste, which further degrades the environment. Further, metals present in Lithiumion batteries, such as cobalt and nickel, are toxic and when these metals are leaked into earth, they can degrade the soil and pollute the groundwater leading to long lasting effects for human and other living creatures.

In addition, fire hazard is also associated with lithiumion batteries. There have been news of mobile batteries suddenly catching fire. There is always a risk of fire if these batteries are not kept properly. Overheating of one energy cell is enough to start the fire and it may spread to other cells. These can be related to a design and production problem; however, occurrence of such events cannot be prevented completely. The presence of toxic metals could potentially lead to serious emission issues in the case of fire. It is well documented that lithiumion battery fires release intense heat along with substantial amounts of toxic gases and smoke. Though gases are emitted in significant quantity, still their characterizations are not well documented. The characterization becomes more difficult due to presence of different types of battery. It was reported during fire tests that large amount of toxic gases such as hydrogen fluoride and phosphoryl fluoride are generated in the range of 20 and 200 mg/Wh and 15–22 mg/Wh, respectively. These fluoride gas emissions are toxic and may pose a potential threat, especially for large Lithiumion battery packs and must be considered for risk assessment and management.

Recycling

There will be a huge surge in demand for omnipresent lithiumion battery with growing popularity of electric vehicles. However, disposal of lithium-ion battery will remain a major concern as the environmental impact of these batteries, as lithium is a reactive alkali metal, are still unexplored. Dumping of spent batteries to landfills will certainly contaminate the soil and pose a serious threat to the ecological balance of the local area. Dumping of lithiumion batteries is not only dangerous to ecological system but also considered as missed opportunity from the economical perception. Hence, recycling can bring down the cost by extracting precious materials, curb detrimental emission, reduce energy consumption, and preserve the natural resources.

Many hurdles are present which restrict the emergence of established technology for recycling lithiumion batteries. One of the prime reasons is that the scientists are mostly occupied in dealing with core issues such as increasing the durability and charge capacity as well as reducing the cost and charging duration. In addition, rapid development in battery technology also restricted the standardization of recycling process. Furthermore, the recycling process, which generally involves melting-and-extraction, or smelting, at high temperature is an exhaustive exercise. These processes not only involve consumption of energy but also emission of a number of harmful gases, which require installation of exhaust treatment devices thereby increasing the cost of the plant. Besides, recovery rate for all the valuable materials such, as most expensive and common cathode metals, cobalt, and nickel, is minimal.

Policy Initiatives

The Indian government is gearing up to promote electric vehicles in Indian market through National Electricity Mobility Mission Plan. Faster Adoption and Manufacturing of Electric Vehicles (FAME II), which links incentive to localization, has been criticized by the industry in the past. Federation of Indian Chambers of Commerce and Industry (FICCI) has also suggested some changes in the existing policies and emphasized that battery swapping model of charging should be included in FAME II. In addition, the focus area of the policymakers is frequently changing. The initial attention was given to vehicle standardization with FAME, which shifted later to manufacturing and now the focus area is charging infrastructure framework. A number of legislations are put in place for electricity sales in India, which is cumbersome to implement effectively. Hence, it is required to review and integrate the existing legislation to make way for one pan-India license. In a similar manner, recycling of lithiumion battery is still in research phase and not fully accepted as a consequence of a number of constrains related to technical, economic issues besides absence of clear-cut regulation. Thus, the need of the hour is to provide a clear-cut farsighted policy integrating all domains of electric vehicles.

Other Issues

Apart from the concern raised above, there are a number of other issues that shed a cloud over the sustainability of electric vehicles programme. In the absence of an effective charging infrastructure, the longer duration of charging present a bigger obstacle in the minds of the customer which forces them to opt for internal combustion engine. Though lithiumion batteries have witnessed many improvements over the last decade, long charging times is still a real issue. Weak energy density is another hindrance which creates 'actual range anxiety' in the mind of the customers. Presently, lithiumion batteries are adequately efficient to cater the requirements of mobiles and laptops. However, these batteries are still inefficient to cater the long range demand of automobile, which restricts the spread of electric vehicle as viable alternative to internal combustion engines. With the existing technology, it seems unclear that whether the electric vehicles are capable enough to propel the commercial vehicles due to requirements of large quantities of batteries which will further add to the cost and weight as well as required larger surface area.

Another challenge is the selection of charger, as AC (alternating current) or DC (direct current) chargers have both advantages and disadvantages. The higher upfront cost of electric vehicles is another crucial area. Though electric

vehicles are coming down in cost, still it is much higher than their gasoline counterpart. The surge in demand for electricity in developing countries like India can pose another challenge that may put at risk to electricity distribution networks, which has already been utilized to its maximum capacity. Lack of charging infrastructure possesses another hurdle, which is by large dependent on location. This really varies from undeveloped to developed countries and from rural to urban areas. As reported by Suzuki that many of the Indian car customers may refrain from buying electric vehicle as they do not have their own parking facility.

Concluding Remarks

In spite of the euphoria surrounding electric vehicle success, there are enough reasons to remain careful. There are many who believe that the oil consumption in the coming future will increase further despite all the optimistic future of electric vehicles. Environment, energy, and housing minister of Finland, Kimmo Tiilikainen has also iterated the same view. Further, U.S. Energy Information Administration has also predicted rise in global oil demand.

India should focus on its indigenous sources of energy for sustainable growth and cater to the ever-increasing energy demand. Cultivation of oil seed in restricted areas, especially in semi-arid or arid land, can boost energy security through local resources and will also boost the rural economy. The high cost of electric vehicles (hybrid or full) justifies the implementation of new strategies to fund research that will further reduce the emission as well as increase thermal efficiency of internal combustion engine. In fact, the prevailing situation will act as a catalyst to bring a holistic approach from all stakeholders for the advantageous evolution and sustainability of internal combustion engine Lastly, in the absence of integration among different stakeholder such as supplier, manufacturer, retailers, it is hard to achieve success and overthrow the legacy of internal combustion engine which have dominated the transport sector since many years. For the time being, the world transport sector, especially the world's goods and services section, will be largely dominated by internal combustion engine fueled with petroleum-derived liquid fuel in the absence of major breakthrough in battery technologies, which can negate the current challenges faced by the electric vehicle sector. However, in the meantime affordability and energy security can be ensured by bringing innovative technology and research in the combustion of internal combustion engine.

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VJTI TECHNOLOGY BUSINESS INCUBATOR, MUMBAI

CREATING A SUSTAINABLE ECOSYSTEM FOR ENERGY STARTUPS

Energy has played a very vital role in the economic growth of our nation. According to the Ministry of New and Renewable Energy, the Indian renewable energy sector is the fourth fastest growing renewable energy market in the world with more focus on recently evolved areas like electrical vehicles, energy storage, microgrid and smart grid. In the recent years there has been a sharp rise in the number of entrepreneurs and startups focusing on these sectors and the ecosystem including incubators and accelerators along with investors have been positively supporting their entrepreneurial endeavors.

In line with these trends, VJTI Technology Business Incubator (VJTI-TBI) was set up in 2017 at the prestigious Veermata Jijabai Technological Institute (VJTI), Mumbai with the support of Department of Science and Technology, Govt. of India under the NIDHI-TBI Scheme. VJTI (established in 1887 as Victoria Jubilee Technological Institute) has been a pioneer in imparting engineering education, research and training ecosystem in the country ever since its inception. Considering the expertise, resources and industry collaborations fostered by VJTI over the last few years it decided to create VJTI-TBI, a platform for supporting ambitious entrepreneurs and startups in the country focusing on thematic areas including energy, cleantech, EV, IoT, AI/ML and cyber security of critical infrastructure.

This award-winning incubator (awarded 'Smart Incubator of the Year' at ISGF Innovation Awards 2020) selects startups and entrepreneurs working in the thematic areas through a robust 2-step process by a panel of eminent experts from industry, academia and investment sector. All selected start-ups under the program are provided with co-working space, access to state-of-the-art lab infrastructure (SCADA & Automation Lab, Power Electronics Lab and AI/ML and Embedded Systems

Lab) equipped to test products and prototypes in the domains mentioned above. In addition, VJTI-TBI also provide advisory services in business management, IPR, finance and accounting, legal and technical domains through collaborations with third party service providers and industry associations. Start-ups incubated with the incubator also get access to free tools including AWS credits, ZOHO platform, Zendesk CRM, Solidworks, MatLab and Simulink licenses and MyOperator cloud telephony credits.

VJTI-TBI has also partnered with various corporates (Larsen and Toubro Infotech (LTI), Emerson, NVIDIA, Siemens and CISCO) and industry bodies (India Electrical and Electronics Manufacturers Association, Cyber Peace Foundation, The Institute of Engineering Technology, India Energy Storage Alliance and India Smart Grid Forum) to provide support the start-ups either through mentoring, funding and infrastructure support (including lab infrastructure).

Some of the promising start-ups and entrepreneurs incubated at VJTI-TBI focusing on energy and cleantech are summarized below:

SMDP Solutions (OPC) Pvt Ltd: Founded by Vishwesh Bhat, SMDPower Solutions, a Goa-based energy startup, has manufactured innovative IoT-based products that help customers manage their energy consumption leading to significant savings. Their existing range of products include Intelligent Common Light Controller, Intelligent Street Lighting System, Intelligent Temperature Controller and Intelligent Sensrecorder for Electricity.

Winner of the 'Prototyping Grant Award' from Goa State Innovation Council, the startup is currently focused on developing an IoT-based product for making Intelligent Air Conditioners. SMDP believes this product will harness the power of CoreLogiQ analytics software and shall reduce AC power bills by upto 50% giving value to customers.

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Torus Robotics Pvt Ltd: Torus Robotics is a Startup India recognized tech start-up working on unmanned ground vehicles (UGV) and robotics. Their flagship technology includes the world's most compact, lightweight and powerful motor technology, which is 50% lighter, 15% more efficient and 10% more cost effective than the commercially imported motors available in the market.

Their flagship product named 'Kalam' is a multipurpose heavy duty amphibious UGV that shall be used for combat, surveillance and land-based logistics. Torus recently signed an MoU with BEML (formerly Bharat Earth Movers Limited), a Govt of India enterprise. They have also been recognized by national and international organizations including DRDO, Climate Launchpad, UN FLCTD and HexGn.

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Punaha Batteries Renescance Pvt Ltd: Punaha Batteries is a cleantech startup which aims to reduce e-waste in the battery industry by upto 50% through a novel mechanism to reduce the number of lead acid and nickel cadmium batteries that are discarded. The startup uses a software-controlled 'desulphation' process to regenerate the batteries, allowing them to be used for up to twice as long.

Punaha has provided battery regeneration services to some big names in the industry including Godrej, Asian Paints, Coca Cola, Future Group, Mac Neill Engg, Naval Dockyard Mumbai, Mazagon Docks Ltd and Johnson & Johnson. The startup was selected among the Top 10 innovators under the 'Springwise Positive Innovation Challenge 2019' organized by Springwise Intelligence (UK) in collaboration with Startup India.

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VJTI-TBI is currently looking to partner with industries and businesses focusing on developing innovations in the energy and cleantech domain for promoting innovation challenges and hackathons. The incubator has already forged partnerships with LTI, ITD Cementation India, SIDBI Capital Ventures and Technotalent Engineering India and raised CSR funding of upto Rs 187 Lakhs for providing seed support to startups and for creating co-working space and prototyping labs. Partnerships with these stakeholders in the relevant domains plays a key role to help the entrepreneurs tide the difficult part of the journey in their initial years. The incubator also plans to onboard between 10-15 startups working in the thematic areas of energy, cleantech, AI/ML, IoT, EV and cybersecurity.

Author:
Dr. Roshan Yedery
Chief Executive Officer
VJTI Technology Business Incubator

CURRENT R&D RENEWABLE

Towards Better Performances for a Novel Rooftop Solar PV System

Solar Energy, Volume 216, March 2021, 518–529
A K Behura, K Ashwini, D K Rajak, C I Pruncu, and L Luciano

Solar photovoltaic (PV) systems are used worldwide for clean production of electricity. Photovoltaic simulation tool serve to predict the amount of energy generated by the PV solar array structure. This paper presents the photovoltaic system installed on the rooftop of the G.D. Naidu Block at Vellore Institute of Technology (Vellore, India). A novel PV plant design is developed here in order to improve the energetic efficiency of an existing PV system. The effectiveness of proposed design is evaluated over an entire year using the PVsyst v6.70 software, which works on accurate plant specifications. For this purpose, Metronome 7.1 weather data sets of ambient temperature and radiation from PVsyst database are used for the investigation. The cost of the proposed PV system and the required payback period are analysed as well. Simulation results demonstrate the superiority of the proposed PV system design over the existing one in terms of the amount of electric energy injected in the grid, energy conversion efficiency, and reductions in CO_2/SO_2/NO emissions. EF

What Determines Environmental Deficit in Asia? Embossing the Role of Renewable and Non-renewable Energy Utilization

Renewable Energy, Volume 168, May 2021, 1165–1176
Muhammad Usman, Khaizran Khalid, and Muhammad Abuzar Mehdi

This study explored the dynamic nexus between financial development, economic growth, non-renewable and renewable energy utilization, trade openness and ecological footprint by utilizing the second-generation panel data approach covering the period from 1990 to 2014 for 20 Asian economies. The inspection of cross-sectional dependency (CSD) tests confirmed that CSD exists across cross-sections. For this intention, the study employed the second-generation panel unit root tests, panel co-integration techniques, augmented mean group (AMG) approach for the estimation of long-run magnitude of the parameters. The empirical findings illustrate that economic growth and non-renewable energy utilization significantly accelerate the environmental deficit, while renewable energy utilization reduces the total environmental damages in the long-run. Furthermore, country-specific outcomes explore the influence of renewable and non-renewable energy utilization on ecological footprint varies in terms of their nature of association, influence in their magnitude and their significance level. Moreover, Dumitrescu and Hurlin (D-H) causality test discovered the feedback hypothesis between ecological footprint and financial development, economic growth, non-renewable and renewable energy utilization and trade openness. Finally, current study expresses the some vital policy implications for Asian countries. EF

Evaluation of Energy Alternatives for Sustainable Development of Energy Sector in India: An Integrated Shannon's Entropy Fuzzy Multi-criteria Decision Approach

Renewable Energy, Volume 171, June 2021, 58–74

S K Saraswat and Abhijeet K. Digalwar

In this paper, conventional and renewable energy sources for sustainable development of energy sector in India are evaluated from multiple perspectives including economic, technical, social, environmental, political, and flexible criteria. An integrated Shannon's entropy multi-criteria decision making (MCDM) method has been used for the evaluation and assessment of these sources. Thermal, gas, nuclear, solar, wind, biomass, and hydro energy options are used as the alternatives in the decision model. Shannon's entropy method is applied to determine the weights of decision criteria, and fuzzy analytical hierarchy process (AHP) method is applied to prioritize sustainable energy alternatives. The output of the proposed model was compared with six different fuzzy MCDM techniques for the establishment of correlation index. Solar energy was shown to be particularly well suited for India followed by wind and hydro energy sources. Later, the study has developed fourteen scenarios, considering the first five sustainable energy sources (solar, wind, hydro, biomass, and gas power), to evaluate the optimal energy mix scenario for the sustainable development of energy sector in India. An optimal energy mix scenario carries the heroic development of solar, wind, and hydro energy with cross border import-export facility for the time frame of the year 2030. EF

Energy, Exergy, and Economic Analysis of an Off-grid Solar Polygeneration System

Energy Conversion and Management, Volume 238, June 2021, 114177

Auroshis Rout, Suneet Singh, Taraprasad Mohapatra, Sudhansu S. Sahoo, and Chetan Singh Solanki

This paper conducts a 3E (Energy, Exergy, Economic) analysis for a novel off-grid solar polygeneration energy technology producing electricity using the solar PV and hot water along with hot air using the solar thermal system. The analysis has been carried out across four Indian provinces such as Andhra Pradesh (AP), Madhya Pradesh (MP), Uttar Pradesh (UP), and Uttarakhand (UTK) located in four climatic zones. For the solar PV unit, the amount of annual electricity production in kWh are 1748, 1799, 1629, 1434 in mentioned four states, and the annual Levelized Cost of Electricity (LCOE) in ₹/kWh are 9.8, 9.6, 10.5, 12 for AP, MP, UP, and UTK respectively. The values of annual average energy efficiency of the solar thermal system in percentage are 64.6 for AP, 64.5 for MP, 64.2 for UP, and 58.3 for UTK, while energy efficiency are found to be 1.3, 1.4, 1.2, and 0.7 in percentage for the mentioned states. For the solar thermal unit, the values of payback period in years are obtained to be 5.2, 5.5, 7.5, 9.4 and the values of Benefit-Cost ratio (BCR) are 1.32, 1.25, 0.90, 0.73 for AP, MP, UP, and UTK respectively. An innovative business model coupled with utility policy is required for large-scale deployment of these sustainable energy technologies. EF

Solar-City Plans with Large-scale Energy Storage: Metrics to Assess the Ability to Replace Fossil-fuel-based Power

Sustainable Energy Technologies and Assessments, Volume 44, April 2021, 101065

Rhythm Singh

It is important to have objective metrics for assessing the value of solar city plans in terms of their ability to avoid fossil fuel based generation. The need is further augmented by the prospect of integration of large-scale energy storage options with the solar city plans. This paper addresses this need by defining a novel metric, energy- credit, along with the established metric, peak capacity- credit, and its slightly modified variant, the 90th percentile of peak capacity- credit (90PCC). The methodology has been illustrated by application to a solar- city plan for Mumbai city in India, along with two custom energy storage scenarios, ES20 and ES40. The ES20 scenario corresponds to shifting 20% of the solar- city generation during the slot 12:00 hours – to 15:00 hours to the slot 18:00 hours – to 21:00 hours; for the ES40 scenario, the corresponding value is 40%. The results show an energy- credit of 29.7% and 21.2% for P50 and P5 levels of solar- city generation, respectively. The metric 90PCC is found to vary from 12.78% for base case to 15.05% for ES20 to 15.45% for ES40, for P5 level of solar- city generation. The corresponding values of 90PCC for P50 level of solar-city generation are 13.72%, 18.82%, and 22.60%, respectively. EF

A Real-time Multi-objective Optimization Framework for Wind Farm Integrated Power Systems

Journal of Power Sources, Volume 498, June 2021, 229914
S Ida Evangeline and P Rathika

Wind energy is a rising industry that is rapidly influencing the global energy environment, leading to pollutant mitigation and ultimately helping to shift the climate change paradigm. The incorporation of wind energy into power grids poses new challenges from the point of view of operating performance for transmission network operators. The inconsistent nature is the most significant issue with wind energy. Wind power differs from time to time and the operator must choose the operation strategy accordingly. In this study, a real-time multiple objective optimal power flow framework is proposed to solve this issue. The related dynamic optimization problem is solved online and the control variables are optimized simultaneously. To guarantee both the feasibility and performance of the proposed method, a multi-objective particle swarm optimization with decomposition is developed. Using modified IEEE 30-bus and IEEE 57-bus test systems, the validation of the proposed approach is described in this research. EF

Learning-based Compilation of Embedded Applications Targeting Minimal Energy Consumption

Journal of Systems Architecture, Volume 116, June 2021, 102116
Akash Sachan and Bibhas Ghoshal

In this study, researchers propose an automated technique of determining the optimal compiler optimization setting for minimum energy consumption utilizing power profile results and performance characteristics from real hardware and machine learning models. The proposed approach on the one hand brings about reduction in energy consumption and on the other releases embedded software developers from making the complicated compiler optimization choices for each application. The proposed five-phase strategy when implemented on multi-core ARM ARM-based ODROID-XU4 experimental platform using the Clang Compiler shows a maximum of 8.43% improvement in power dissipation and a maximum of 27.27% in energy consumption for MiBench and Polybench representative benchmarks in comparison to state-of-the-art energy aware compilation strategies. EF

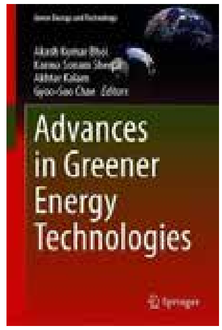
High Temperature Superconducting Material-based Energy Storage for Solar-Wind Hybrid- generating Systems for Fluctuating Power Management

Materials Today: Proceedings, Volume 42, Part 2, 2021, 1122–1129
K Aseem and S Selva Kumar

This paper proposes a hybrid energy management system based on the Super conductive magnetic material and the lead acid battery to provide power stabilization in the grid-connected unstable microgrid. Here, second-generation High Temperature Superconducting (HTS) material is used as Super Conducting Magnet Energy Storage (HTSMES) which exhibits a high irreversibility field and critical current density within an active magnetic field. The proposed system may be a good solution to minimize the impact of the Point of Common Coupling (PCC) power variability during fault condition. To improve the efficiency and flexibility of the proposed system, the two hybrid power sources are connected via dual input single output zeta converter. The HTSMES is used to minimize the difference in active power during fault and to give the reactive current to handle the fault. Grid connected microgrid with HTSMES-battery was simulated using the MATLAB Simulink platform and tested using an energy management algorithm with and without the presence of fault. The system proposed is demonstrated with detailed simulation results. EF

Advances in Greener Energy Technologies (Green Energy and Technology)

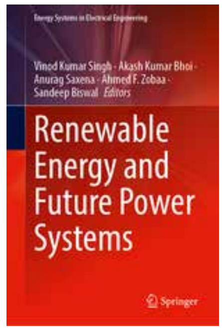
This book presents both the importance of energy transition and its associated difficulties. The second edition of *Energy Transition* provides an explanation of the physical concepts of energy and power and also reviews global energy consumption and our dependence on energy. Further, it discusses the links between the economy and energy. It explains the drawbacks and dangers of different energy sources and tries to compare them. By reviewing future energy resources, it evaluates several transition scenarios. The book shows that the laws of physics prevent the emergence of simple, pleasant solutions, but it proposes potential solutions and encourages readers to develop better processes from energy sources to production and consumption. EF



Authors/Editors: Akash Kumar Bhoi, Karma Sonam Sherpa, Akhtar Kalam, Gyoo-Soo Chae

Renewable Energy and Future Power Systems

This book discusses advanced technologies for applications in renewable energy and power systems. The topics covered include neural network applications in power electronics, deep learning applications in power systems, design and simulation of multilevel inverters, solid state transformers, neural network applications for fault detection in power electronics, etc. The book also discusses the important role of artificial intelligence in power systems, and machine learning for renewable energy. This book will be of interest to researchers, professionals, and technocrats looking at power systems, power distribution, and grid operations. EF



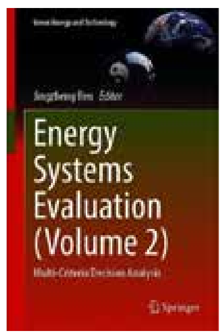
Authors/Editors: Vinod Kumar Singh, A.K. Bhoi, A. Saxena, A. F. Zobaa, S. Biswal,

Energy Systems Evaluation (Volume 2): Multi-Criteria Decision Analysis

This book presents various multi-criteria analysis methods for sustainability-oriented analysis and decision-making for energy systems, under various different conditions and scenarios. It presents methodologies to answer the questions relating to which of the options are the most sustainable among the alternatives, and how multi-criteria decision analysis methods can be used to select the most sustainable energy systems.

A systematic innovative methodological framework is presented, which enables the most appropriate energy system to be selected under different conditions including:

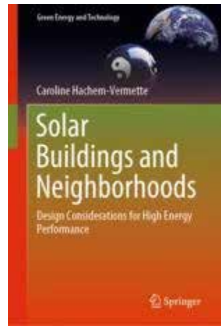
- Scientific decision support tools for sustainable energy system selection;
- Fuzzy, grey, and rough sets based multi-criteria decision analysis;
- Decision-making models under uncertainties; and
- The combination of life cycle thinking and multi-criteria decision analysis



Editor: Jingzheng Ren

Solar Buildings and Neighborhoods: Design Considerations for High Energy Performance

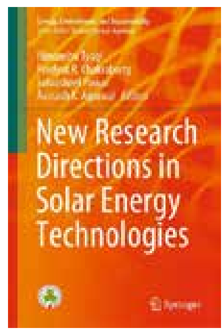
This book presents the main principles for designing buildings and neighborhoods with increased potential to capture and utilize solar energy. It discusses practical issues in the design of the built environment and their impact on energy performance; and a range of design considerations, from building components (e.g. the building envelope) to urban planning issues (e.g. density and street layouts). In addition to design guidelines on how to increase buildings' potential to capture solar energy, the book provides creative tips to increase the aesthetic value of solar technology integration in buildings. Helping readers plan energy-efficient buildings with innovative building envelope technologies, and to understand the impact of early-stage design considerations on the energy performance of buildings and communities, the book offers a valuable source of information for building professionals, including architects, engineers, and urban planners. It can also serve as a reference guide for academics and students of energy efficiency in buildings and urban planning. EF



Author: Caroline Hachem-Vermette

New Research Directions in Solar Energy Technologies

Applications of solar energy have been expanding in recent years across the world. This monograph details such far-reaching and important applications which have the potential for large impact on various segments of the society. It focuses solar energy technologies for various applications such as generation of electric power, heating, energy storage, etc. This volume will be a useful guide for researchers, academics and scientists.. EF



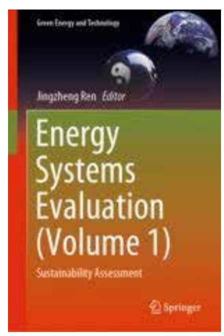
Editors: Himanshu Tyagi, Prodyut R. Chakraborty, Satvasheel Powar, Avinash K. Agarwal

Energy Systems Evaluation (Volume 1): Sustainability Assessment

This book presents various methods for sustainability assessment of energy systems, under various different conditions and scenarios. It answers the questions of how to measure the sustainability of energy systems by adopting appropriate metrics and methods. This book provides readers with a comprehensive view of the frontiers of sustainability assessment methods for energy system analysis. It presents various methodologies, allowing readers to understand:

- the complete metrics for sustainability assessment;
- life cycle thinking for sustainability assessment of energy systems; and
- the advanced sustainability assessment methods for energy systems.

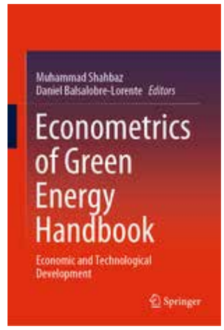
This book is of interest to researchers, engineers, decision makers, and postgraduate students within the field of energy systems, sustainability, and decision analysis. EF



Authors: Vinod Kumar Singh, Akash Kumar Bhoi, and Anurag Saxena

Econometrics of Green Energy Handbook: Economic and Technological Development

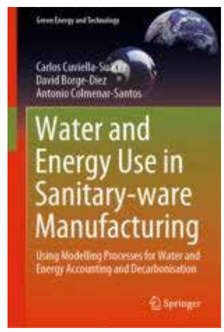
This book gathers cutting-edge studies on the relationship between energy innovations, economic growth, environmental regulation, promotion of renewable energy use, and climate change. Building on the research discussed in the editor's previous book Decarbonization and Energy Technology in the Era of Globalization, it discusses recent developments such as the impacts of globalization and energy efficiency on economic growth and environmental quality. It also explores the ways in which globalization has benefited green energy development, e.g. the expansion of new technologies and cleaner machinery, as well as the problems it has caused. Written by respected experts, the respective contributions address topics including econometric modelling of the behaviour of and dynamics between economic growth and environmental quality, aspects of energy production and consumption, oil prices, economic growth, trade openness, environmental quality, regulatory measures, and innovations in the energy sector. Providing a comprehensive overview of the latest research, the book offers a valuable reference guide for researchers, policymakers, practitioners and students in the fields of renewable energy development and economics.



Editors: Muhammad Shahbaz, Daniel Balsalobre-Lorente

Water and Energy Use in Sanitary-ware Manufacturing: Using Modelling Processes for Water and Energy Accounting and Decarbonisation

This book analyses and quantifies how and where energy and water are consumed by the ceramic sanitary-ware industry and provides solutions as to how to reduce this. The whole production process is mapped, including modelling methods. The book begins by providing an introduction to ceramic sanitary-ware production and types of factories casting technology. It then moves on to discuss the process and energy modelling for the production line, analysis of energy and water consumptions and proposals for improvements. The last chapter presents the practical implementation of the selected modelling configuration. This book is of particular interest to water and energy management professionals within the ceramic industry, but the methods are of interest to those in other production industries as well.



Authors: Carlos Cuviella-Suárez, David Borge-Diez, Antonio Colmenar-Santos

RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

Holograms increase solar energy yield

A team of researchers recently developed an innovative technique to capture the unused solar energy that illuminates a solar panel. As reported in the Journal of Photonics for Energy (JPE), they created special holograms that can be easily inserted into the solar panel package. Each hologram separates the colors of sunlight and directs them to the solar cells within the solar panel. This method can increase the amount of solar energy converted by the solar panel over the course of a year by about 5 percent. This will reduce both the cost and the number of solar panels needed to power a home, a city, or a country.

The holographic light collector combines a low-cost holographic optical element with a diffuser. The optical element is situated symmetrically at the center of the photovoltaic module to obtain the maximum effective light collection. The team computed the annual energy yield improvement for Tucson, Arizona, and presented a reproducible method for evaluating the power collection efficiency of the holographic light collector as a function of the sun angles at different times of day, in different seasons, and at different geographical locations. The enhancement of approximately five percent in annual yield of solar energy enabled by this technique can have large impact when scaled to even a small fraction of the 100s of gigawatts of photovoltaics being installed globally.

https://www.sciencedaily.com/releases/2021/05/210525160839.htm

Scientists debut most efficient 'optical rectennas,' devices that harvest power from heat

Researchers have tapped into a poltergeist-like property of electrons to design devices that can capture excess heat from their environment and turn it into usable electricity. They developed a device, which is roughly 100 times more efficient than similar tools used for energy harvesting. Rectennas (short for "rectifying antennas"), work a bit like car radio antennas. But instead of picking up radio waves and turning them into tunes, optical rectennas absorb light and heat and convert it into power. They're also potential game changers in the world of renewable energy. Working rectennas could, theoretically, harvest the heat coming from factory smokestacks or bakery ovens that would otherwise go to waste. Some scientists have even proposed mounting these devices on airships that would fly high above the planet's surface to capture the energy radiating from Earth to outer space.

The problem, however, is that to capture thermal radiation and not just microwaves, rectennas need to be incredibly small many times thinner than a human hair. And that can cause a range of problems. The smaller an electrical device is, for example, the higher its resistance becomes, which can shrink the power output of a rectenna. However, the researchers decided to add two insulators to their devices, not just one. That addition had the counterintuitive effect of creating an energetic phenomenon called a quantum "well." If electrons hit this well with just the right energy, they can use it to tunnel through the two insulators experiencing no resistance in the process. It's not unlike a ghost drifting through a wall unperturbed.

https://www.sciencedaily.com/releases/2021/05/210518114809.htm

A safer, greener way to make solar cells: Toxic solvent replaced

A team of researchers have found a way to replace the toxic, unsustainable solvents currently needed to make the next generation of solar technology. They have discovered that a non-toxic biodegradable solvent called γ-Valerolactone (GVL) could replace these solvents without impacting cell performance.

Following are the GVL's list of advantages that could improve the commercial viability of carbon perovskite solar devices :

- It is made from sustainable feedstocks
- There are no legal issues in its use around the world
- It is suitable for use in large-scale manufacturing processes
- It is non-toxic and biodegradable

According to one of the researchers, to be truly environmentally sustainable, the way that solar cells are made must be as green as the energy they produce. As the next generation of solar technologies approaches commercial viability, research to reduce the environmental impact of large-scale production will become increasingly important. This discovery will enable countries that have previously been unable to participate in this research to become part of the community and accelerate the development of cleaner, greener energy.

https://www.sciencedaily.com/releases/2021/05/210519163642.htm

Scientists develop transparent electrode that boosts solar cell efficiency

Traditional solar cells are made from silicon, but scientists believe they are approaching the limits of the technology in the march to create ever more efficient solar cells. Perovskite cells offer a promising alternative and stacking them on top of the traditional cells can create more efficient tandem devices, the scientists said. The perovskite solar cell that the team developed achieved 19.8% efficiency, a record for a semitransparent cell. And when combined with a traditional silicon solar cell, the tandem device achieved 28.3% efficiency, up from 23.3% from the silicon cell alone. The team found that chromium used as a seed layer allowed the gold to form on top in a continuous ultrathin layer with good conductive properties. The scientists said solar cells made with the gold electrodes are stable and maintain high efficiencies over time in laboratory tests.

https://www.sciencedaily.com/releases/2021/05/210528114132.htm

Airports could generate enough solar energy to power a city

Researchers compared electricity generated by residential solar panels in a regional Australian city to the potential green energy production of 21 leased federal airports. They found if large-scale solar panels were installed at the airports, they would generate 10 times more electricity than the city's 17,000 residential panels, while offsetting 151.6 kilotons of greenhouse gasses annually. Researchers determined the optimum tilt angle for the solar arrays for each airport, to maximise efficiency. Perth Airport had most energy-generating potential; placing solar panels there could produce almost twice the solar output of Bendigo, equal to the combined production from Adelaide, Sydney, Moorabbin and Townsville airports. Even Melbourne Airport alone would outperform Bendigo's annual solar electricity production by almost 12 gigawatt hours a year. Airport buildings less suited to solar panels could still be useful for ground-mounted solar systems, the study found. The research underlined the necessity for energy policies to include a plan for installing solar panels at airports.

https://www.sciencedaily.com/releases/2021/04/210426140855.htm

Quantum mechanics paves the way for more stable organic solar cells

Organic solar cells have many advantages compared with traditional silicon-based solar cells. They can be manufactured cheaply at a large scale using printing presses, and they are light, malleable and flexible. The problem is that today's organic solar cells are not as stable and effective as silicon-based solar cells. In a new study, a research group has taken on this problem and found a way that can lead to more cost-effective solar cell technology. Basically, this is about making sure the energy in the solar cells is effectively transferred to the right place. Organic solar cells contain two materials, and the absorbed energy from the sun needs to be diffused to travel and to the interface between the materials. But diffusion is an ineffective process since the energy travels slowly and risks being lost as heat before it reaches this interface. The solution has been to blend the two materials in solar cells to reduce the distance and so the energy reaches the interface more quickly. Unfortunately, this also leads to the solar cells not being in thermodynamic equilibrium, making design less durable over time than it could be.

The researchers show that the new method allows the energy to be transferred over a longer distance, which means that the complicated blending of materials in solar cells can be avoided. The key behind the method is quantum effects, where light and material are combined into hybrid light-matter states. They showed that the energy travels faster to the interfaces when the materials are strongly coupled. This means that the materials in solar cells do not need to be physically blended since they are blended at the quantum level. This also leads to the system being in thermodynamic equilibrium.

https://www.sciencedaily.com/releases/2021/05/210511123552.htm

Novel crystalline form of silicon could potentially be used to create next-generation electronic and energy devices

A team of researchers developed a new method for synthesizing a novel crystalline form of silicon with a hexagonal structure that could potentially be used to create next-generation electronic and energy devices with enhanced properties that exceed those of the "normal" cubic form of silicon used today.

Like all elements, silicon can take different crystalline forms, called allotropes, in the same way that soft graphite and super-hard diamond are both forms of carbon. The form of silicon most commonly used in electronic devices, including computers and solar panels, has the same structure as diamond. Despite its ubiquity, this form of silicon is not actually fully optimized for next-generation applications, including high-performance transistors and some photovoltaic devices. While many different silicon allotropes with enhanced physical properties are theoretically possible, only a handful exist in practice given the lack of known synthetic pathways that are currently accessible.

Hexagonal forms of silicon have been synthesized previously, but only through the deposition of thin films or as nanocrystals that coexist with disordered material. The newly demonstrated Si24 pathway produces the first high-quality, bulk crystals that serve as the basis for future research activities. Using the advanced computing tool called PALLAS, which was previously developed by members of the team to predict structural transition pathways -- like how water becomes steam when heated or ice when frozen -- the group was able to understand the transition mechanism from Si24 to 4H-Si, and the structural relationship that allows the preservation of highly oriented product crystals.

https://www.sciencedaily.com/releases/2021/05/210511123552.htm

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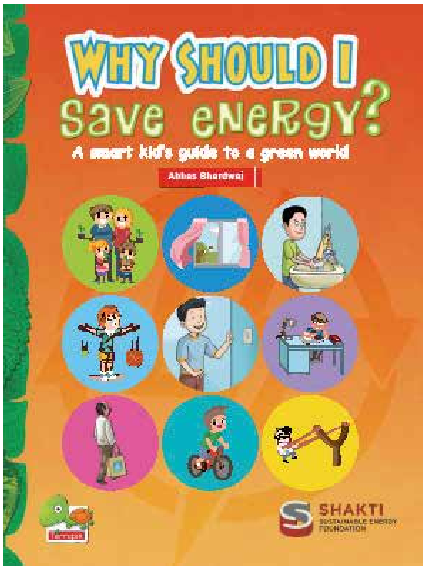

WHY SHOULD I Save ENERGY?

A smart kid's guide to a green world

Abhas Bhardwaj

• 2020 • 210 x 280 mm • 56 pages
• Hardback • ISBN: 9788179935798
• Genre: Pictorial-Reference • Price: ₹250.00

Ages: 12+ years

Did you know that energy consumption by humans has increased by at least 30,000 times in the last 5000 years? In Delhi alone, there are over 80,000 trucks that run on the city roads every night. They emit un-burnt fossil fuels from their exhausts. Isn't it terrifying that over 1 million seabirds and 100,000 sea mammals are killed by pollution every year?

Why Should I Save Energy? is a comprehensive book that will introduce children to different forms of energy, history of fossil fuels, great scientists and their inventions, and more importantly, to the problems our planet faces with depletion of natural resources. Filled with eye-opening facts, beautiful pictures, multiple activities, and a quiz that helps reinforce learning; this book is the perfect guide to help you become an energy saver.

Table of Contents

About the Author

Abhas Bhardwaj has studied botany and economics. Currently, he works as a market researcher. He has an avid interest in the environment and likes to share his enthusiasm with young minds. In his inimitable style, he likes to approach serious questions with humour.

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TECHNOLOGY AND POLICY CONSIDERATIONS FOR THE FUTURE OF ELECTRICITY GRID

Technology and policy considerations are important for the future of electricity grid in India. In conversation with **TCA Avni** for Energy Future, **Mr Sanjay Kumar** Banga discusses the way in which DISCOMs can play a key role in promoting energy efficiency in rural areas, and help the country. He is also suggests that DISCOMs need to bring efficiency in cost structure and reduce losses along with getting involved with EV infrastructure to raise revenues.

Universal household electrification in India marks a major milestone in our sustainable development journey, with reliable supply being the next major challenge. A 2020 CEEW study noted that an average Indian household receives 20.6 hours of grid supply. Could you talk about the technical challenges in power delivery, and the potential solutions and way forward?

The distribution sector in India is primarily served by the state DISCOMs. While very few urban cities in India, such as Delhi, Mumbai, Ajmer, Kota, Kolkata, Ahmedabad to name a few, are run by private players (such as TATA Power, Torrent, CESC) through the PPP or Distribution Franchisee model, larger part of the country and rural areas are still operated by the state DISCOMs.

Distribution in India is the weakest link in the power chain. The financial ill-health of the state DISCOMs bundled with poor condition of network infrastructure add to the woes of the distribution sector in India.

Until 10 years ago, there were power supply constraints; however, today, India is a generation surplus country with no constraints on the transmission side with the formation of a single national grid. Despite this surplus situation, consumers, especially in the rural parts of the country, are deprived of 24/7 power supply. This is mainly because the state DISCOMs are unwilling to buy 100% of the required power for their consumers and in certain situations where the DISCOMs are willing, the condition of assets is not up to the mark , resulting in power shutdown to consumers lasting upto 3–4 hours.

The grim situation arises mainly due to two issues – first being that the state DISCOMs do not have enough money to manage the network. With the operation and maintenance (O&M) costs allowed by the regulator, they are barely able to manage the outages and, thus, there is no concept of preventive maintenance. This is a major difference – private companies are focused on carrying out preventive maintenance to ensure that the health of assets is well-maintained and that there is redundancy in the network to maintain reliability of power. For example, on the onset of monsoon, pre-monsoon checks/activities are carried out rigorously to ensure that the service stations are at or above the flood levels to avoid water logging; removal of vegetative growth to ensure no damage to network, etc. Contrary to this, the state DISCOMs do not carry out any preventive maintenance of their assets thereby causing many forced outages and trippings (a 11 kV feeder trips more than a thousand times in a year), leading to unreliable supply.

Second, state DISCOMs have not invested in technology to monitor their network and its operations. For example, each DISCOM should have supervisory control and data acquisition (SCADA) systems which control the entire network and monitor their parameters to identify faults and tap redundant supply from another source. It is critical that power utilities invest in technologies to improve reliability. When a DISCOM is able to supply more units, the operating cost per unit decreases – more the power supplied to C&I consumers, the lesser will be the tariff and lower will be the AT&C losses. So, there definitely is a case to reducing capital expenditure by use of technology and prudent planning.

When Tata Power took over Odisha, we faced similar issues of deteriorated health of network, lack of technology to control network, no data availability for planning, no concept of preventive maintenance. To hit the ground running and tackle these issues at the foremost, we now have annual maintenance contracts and teams deployed in place and checklists to ensure availability of electric infrastructure. They do patrolling of sub-transmission lines to ensure that there are no outages, and we are investing in the state-of-the-art technologies for better monitoring and control of assets.

Could you also talk a little about what you see as the role and scope of energy efficiency improvements in improving electricity supply?

It is clearly evident how the LED replacement programme in India itself has yielded excellent results to save energy. In Delhi, Tata Power - DDL made sure that all streetlights were changed from the conventional to LED lights, and the monthly savings on electricity costs was so substantial that we were able to fund the LED project itself.

It is important for each of us to understand how energy efficiency helps you. First, for consumers who consume electricity in the category of 100–200 units, the government provides a subsidy that reduces the monthly bill, thus making them better and responsible paying consumers. Further, with energy consciousness and use of energy efficient appliances, the consumption of energy reduces, which earns the consumer a lower slab benefit – a low tariff. There is a huge scope of promoting use of energy efficient appliances by the distribution utilities and 'Less is More' should become the mantra to promote as lower electricity bills ensure regularity in bill payment which relieves the utility from accumulated unpaid dues. DISCOMs can play a good role as they touch base each consumer every month when they go to collect meter readings and distribute bills. They can promote energy efficiency in rural areas, and it can tremendously help India.

Some DISCOMs in Delhi had run programmes for incentivizing energy-efficient appliance purchase- could you talk about the experience of these?

We have had a very good experience in Delhi, where the regulator allowed some amount for Demand Side Management (DSM) programmes. This DSM programme essentially incentivizes the consumers with a rebate for opting to use energy-efficient appliances.

For example, Tata Power - DDL has set a replacement programme for air conditioners. We ran a programme for those who were using older, energy-inefficient air conditioners. Under the programme, they could buy a branded BEE-rated 5-star air conditioner at a price lower than the MRP and they received an exchange price for their old air conditioner. The regulator gave the balance amount to the consumers as a rebate to incentivize replacement.

The regulator can definitely play the role of a catalyst in ensuring success of the responsible use of energy by approving more such programmes. Similar such programmes that run across our Delhi and Mumbai distribution utilities are energy-efficient fans with BLDC motors, LED tubelights, etc. Here the consumers hardly pay 10–20% more cost than that of conventional appliance but benefit a lot on saved energy costs, as these appliances consume only a quarter of the energy that a conventional model would.

There was a 2019 research paper by NBNL on the potential of superefficient appliances as part of the initiative to providing reliable and sustainable electricity access. However, given already low rural consumption, would this cause a problem in supplying there?

The per capita consumption in rural areas is very low. For example, in South Odisha, where we are currently serving, the per capita consumption is only 350 units, which is only about 30 units per month. In times to come and as our network penetrates these rural areas with 24x7 power supply, even with energy efficiency programmes, the per capita consumption is only going to increase, as these households will also move to buy other energy consuming appliances, such as refrigerators, mixers, coolers. With this, we can only expect the load demand to grow. And as incomes and savings rise, the capability to buy more appliances will only increase thus increasing the overall energy demand in the country .

[1] Amol Phadke, Won Young Park, Nikit Abhyankar. Providing reliable and financially sustainable electricity access in India using super-efficient appliances. Energy Policy (2019) (https://www.sciencedirect.com/science/article/pii/S0301421519303854)

Given, as you mention, the low level of consumption amongst the newly electrified and the scale of infrastructure still required, India's latent electricity demand is enormous. Could you talk about what you see as the challenges and opportunities for distribution utilities?

Yes, tremendous latent demand exists in distribution utilities. In the current scenario of things, rural areas have very high losses so the utilities do not take restoration on priority and these outages last for long hours. What utilities can do to reduce their losses? One, it is very important that they do the right kind of billing and ensure that each consumer has a metered connection which is mapped in billing systems. Saubhagya scheme, for example, has been a very successful electrification programme where each household has been provided a meter and they started consuming electricity. However, since their meters were not mapped in the billing system, they did not receive the bills for many months. As a result of this, their consumption actually resulted in utilities only incurring more losses. It is essential that the utilities have a good discipline on metering, billing, reading, and collection activities. Once you have that and you can reduce losses, the financial conditions of utilities will improve, which will in turn allow them to spend more money on network maintenance, allowing them to increase power supply and in the end will ensure sustainable business. The current loss levels in rural areas are nearly to the tune of 50–60% which only burdens the utilities with no incentive to supply power to these areas and maintain networks which ultimately result in poor power supply condition.

On policy recommendations on promoting electrical cooking in rural areas, some concern was raised on the impact on the load curve, as cooking is typically done during off-solar hours (in the mornings and evenings), and this could increase the 'peakiness' of the load. How would you comment on this?

I would say it does not matter, even if it is not in solar hours. The thermal PLF is currently 58–60%. The more the thermal assets are in use, the lower is their cost of generation. And as I mentioned, the per capita consumption is so low, increasing the demand further will only lead to better utilization of assets. For example, if a DISCOM's fixed operating cost is Rs 10, and it is serving 10 units – the fixed cost per unit is Rs 1. Now if the consumer uses 20 units, the fixed cost does not increase proportionally but the operating cost comes down by nearly 30 -40%. So, more delivery of energy in rural areas is good, because the assets that have been set up there are currently barely utilized to 20% of their existing capacity. In addition, if you subsidize electrical cooking, you will also reduce the air pollution caused by biomass burning and improve health outcomes.

So, it is only pertinent that we promote as much electricity consumption in rural areas as possible, whether it is from fossil fuel plants or solar, because right now India is at a very low level of consumption. As I mentioned earlier, when you increase the demand, the tariff will come down, and the more tariff reduces, the demand will increase even further, and this increase will allow more renewables to come online, making the whole system more sustainable. So, the focus should be on creating more demand in urban as well as in rural areas.

While India's ambitious renewable energy programme has seen recent solar and wind auctions delivering some of the lowest electricity prices in the power system, there are operational and technical costs to integrating higher shares of renewables. Could you talk about the experience of distribution companies in this regard, and your view on the next steps?

In most of the states which I have worked with, the problem has been of the delay in providing net metering connections. We find that solar costs and rooftop solar costs are on a downwards trend which enables even households in tier 2 towns and rural areas to install solar systems. The real problem is that when someone goes to the DISCOM and asks for net metering, and there is a delay in getting the connection. This is because the DISCOM has no incentive to provide these connections but only lose energy costs because of diversion to renewable sources and not to their account. This is a process problem – one which is quite prevalent in most DISCOMs and needs addressal at policy level.

On the technology side, I do not see much challenge presently, as we have not reached such a high penetration level where this would create a problem of grid instability or more technical loss due to back feeding. Let us take a distribution transformer of 100 kV; you have problem if at the downside you have a solar installation that is more than 70–80%. i.e. around 85 kV, so if the electricity coming in from the grid is less and the solar power starts feeding into the main grid, then you have a reverse power problem which can increase technical losses in the system. In rural areas we still have very limited organized solar players. Good financing schemes are minimal and once micro-finance opportunities come up and good solar rooftop players establish themselves in rural areas with competitive rates, this market will expand.

And what about utility scale solar?

Distribution utilities do not set up solar plants–what they have is a Renewable Purchase Obligation (RPO). For that, as per regulations, they have to undergo a tendering process to discover the lowest cost supplier to procure power. It is for big EPC players to set up the big solar plants, and they try to set these up in places where land is cheaper and connectivity is not an issue.

Big solar plants come through SECI (Solar Energy Corporation of India); they issue notices to DISCOMs on the availability of power and its price. Since DISCOMs have to meet their RPO obligations, they take power from SECI. There are many distribution utilities that are taking power from SECI, and there are many who think they can get better prices from the market, and they float their own RfP to meet their RPO obligation.

In addition to the transition to renewables, the power sector is also transitioning away from traditional 'linear' mode of electricity generation and supply to increasingly decentralized modes. In its FY 2019–20 petition, MSEDCL (Maharashtra's state DISCOM) petitioned for the adoption of gross metering instead of net metering for rooftop solar, arguing that net metering allows consumers who would otherwise have paid higher (subsidizing) tariffs to show low overall consumption, which not only impacts the utility's ability to collect cross-subsidy, but also allows those consumers to become 'subsidized instead of subsidizing'[2]. Others have argued that if rooftop solar 'prosumers' supply the grid with surplus solar when the sun shines, but draw compensatory power in the evening, then the prosumers are effectively treating the grid as an expensive battery, and are not sufficiently paying for the privilege[3]. Could you talk your views on such impacts of distributed renewables on existing institutional and infrastructure frameworks?

There are a few points here that are important. When Germany and others wanted to promote renewable power in their countries, they came out with the concept of feed-in tariffs, where if you are feeding solar power into the grid, you would earn incentives. In India, retail solar prices have plunged to such an extent that you are reaching a stage where you start losing industrial and commercial (C&I) consumers in areas where consumers have the capacity to install solar plants. Now, what is going to happen? The tariffs in India for C&I consumers is very high, in spite of the national tariff policy capping it to 20% of average cost of supply. In many states, C&I consumers pay almost 150% of the average cost of supply; if the average cost of supply is Rs 7, they are actually paying Rs 11 for each unit of power they consume.

2 Details available at https://www.mahadiscom.in/wp-content/uploads/2018/07/MSEDCL-MTR-Petition-Searchable-Format.pdf

3 Details available at https://www.financialexpress.com/opinion/new-electricity-consumer-rules-reading-the-impact-on-rooftop-solar-right/2201407/

By contrast, if they install solar plants, their cost of generation would be not more than Rs 5 per unit. We will see an increasing migration of C&I consumers from distribution companies. If battery costs come down, these consumers will be able to get 24/7 supply at around Rs 7 or 8, instead of the Rs 11 they are currently paying. If they start moving away, then you will be forced to increase tariffs for residential consumers. And as you increase the tariffs for residential consumers, you will reach a stage where many of the residential consumers will also start leaving the distribution companies. And this will lead to a very grim situation for DISCOMs. The institutional framework of distribution companies will change completely in the next few years if we do not bring efficiency in cost structure and reduce losses.

So the next question is how can distribution companies avoid this? DISCOMs need to generate additional revenue to reduce tariffs, similar to the way newspapers use income from advertising to subsidize costs of production. They can get involved in EV infrastructure to raise revenues and can also engage customers in the other services such as helping them with rooftop solar installations. In a decentralized mode, customers and distribution utilities have to engage more for energy efficiency programmes, and DISCOMs have to engage more in generating other revenues so that tariffs can be reduced. This is the only way DISCOMs would be able to run a sustainable business. Otherwise with time, you will find DISCOM customers migrating and DISCOMs will only become a network support provider, earning revenue from minimum wheeling costs only. The distribution sector will change if we do not bring technologies, do not improve efficiencies, do not create opportunities to earn from other streams of revenue to reduce our tariffs.

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NATIONAL AND INTERNATIONAL EVENTS

NATIONAL

International Conference in Advances in Power, Signal, and Information Technology
08–10 October 2021
Bansuri Guru Auditorium, Bhubaneswar, India
Website: https://10times.com/e14s-kzdz-4s45

SolarEx
21–23 October 2021
BTI Ground/ D.I.E.T Satna, Satna, India
Website: https://10times.com/e1zf-57hp-45gg

POWERGEN India
27–29 October 2021
Pragati Maidan, New Delhi, India
Website: https://10times.com/pgindia

World Wind Energy Conference and Exhibition
24 November 2021
New Delhi, India
Website: https://10times.com/e1zz-0fg6-z2z4

INTERNATIONAL

Solar Solutions International (SOLSOL)
28–30 September 2021
Expo Haarlemmermeer, Vijfhuizen, Netherlands
Website: https://10times.com/solar-solutions

Intersolar Europe
06–08 October 2021
Exhibition Munich, Munich, Germany
Website: https://10times.com/intersolar-expo

Dubai Solar Show
05–07 October 2021
Dubai Exhibition Centre, Mina Jebel Ali, UAE
Website: https://www.wetex.ae/

Energy
05–07 October 2021
NEC, Birmingham, UK
Website: https://10times.com/efw-expo

Electricity Transformation Canada
17–19 November 2021
Metro Toronto Convention Centre (MTCC) South Building, Toronto, Canada
Website: https://10times.com/solar-canada

RENEWABLE ENERGY AT A GLANCE

Programme/Scheme wise Physical Progress in 2020-21 & Cumulative upto Aug, 2021			
Sector	**FY 2020–21**		
	Cumulative Achievements (as on 31.03.2021)	**Achievements (Apr-Aug 2021)**	**Cumulative Achievements (as on 31.08.2021)**
I. Installed RE Capacity (CAPACITIES IN MW)			
Wind Power	39247.05	444.10	39691.15
Solar Power - Ground Mounted	35645.63	3168.86	38814.49
Solar Power - Roof Top	4439.74	1046.54	5486.28
SPV Systems (Off-grid)	1150.66	160.46	1311.14
Small Hydro Power	4786.81	21.00	4807.81
Biomass (Bagasse) Cogeneration)	9373.87	25.00	9398.56
Biomass (non-bagasse) Cogeneration)/Captive Power	772.05	0.00	772.05
Waste to Power	168.64	0.00	168.64
Waste to Energy (off-grid)	218.95	14.24	233.20
Total	**95803.40**	**4880.20**	**100683.32**

Source: https://mnre.gov.in/the-ministry/physical-progress

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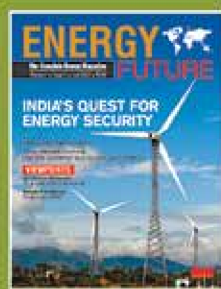

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